ECSE 354 – Electromagnetic wave propagation

LAB 2: Introduction to a Transmission Lines Circuit Board

Week 1 – Theory – Thevenin equivalent and propagation velocity

OBJECTIVE – Thevenin equivalent circuit

Upon completion of this exercise, you will be familiar with the various sections of the TRANSMISSION LINES circuit board. You will know how to replace the STEP GENERATOR of this board by its Thevenin equivalent circuit. You will be able to determine the voltage across a load connected to this generator, using the voltage divider rule.

The TRANSMISSION LINES Circuit Board

The five sections that make up the TRANSMISSION LINES circuit board are as follows:

- TRANSMISSION LINEs, A and B;
- AUXILIARY POWER INPUT;
- STEP GENERATOR;
- SIGNAL GENERATOR;
- LOADs.

Locate and examine each section of the circuit board.

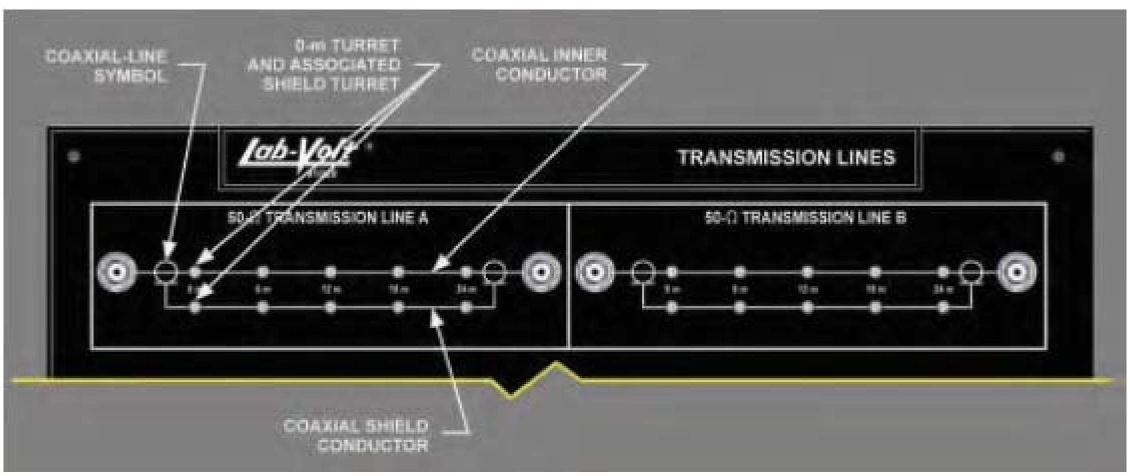

Figure 1.1: Transmission Lines A & B

TRANSMISSION LINEs A and B each consists of a 50-Ω RG-174 coaxial cable having a length of 24 meters (78.7 feet). These lines can be connected end-to-end to obtain a total line length of 48 meters (158 feet). Each line has the following:

• A BNC connector at both its sending and receiving ends.

• Five probe turrets with their associated coaxial-shield turrets that permit observation and/or measurement of the signal along the entire length of the line with an oscilloscope.

The posts are equally distributed along the line, thereby dividing the line into four segments of equal length [6 meters (19.7 feet) each].

Figure 1.2: The AUXILIARY POWER INPUT

The AUXILIARY POWER INPUT section, shown in Figure 1.2, is used to power the TRANSMISSION LINES circuit board with an external ±15 VDC power supply. The LED's in the AUXILIARY POWER INPUT section are on (lit) when adequate power is supplied from the external supply.

Figure 1.3: The STEP GENERATOR

The STEP GENERATOR, shown in Figure 1.3, delivers a 50-kHz signal consisting in a rectangular pulse that occurs every 20µs. The STEP GENERATOR output signal is available at five BNC connectors, each connector corresponding to a different generator output impedance.

Figure 1.4: The SIGNAL GENERATOR

The SIGNAL GENERATOR, shown in Figure 1.4, delivers a sinusoidal signal whose frequency can be adjusted between 5 kHz and 5 MHz, using the FREQUENCY knob. The SIGNAL GENERATOR output signal is available at three BNC connectors, each connector corresponding to a different generator output impedance. A REFERENCE OUTPUT, consisting of two banana plugs, provides a voltage proportional to the frequency of the SIGNAL GENERATOR output signal, that is, 1 V per MHz of the generated signal. Consequently, the SIGNAL GENERATOR output frequency can be measured by connecting a DC voltmeter to the REFERENCE OUTPUT.

The LOAD section, shown in Figure 1.5, consists of a network of resistors, inductors, and capacitors that can be configured in various ways, through the setting of toggle switches. A BNC connector located at the LOAD-section input permits connection of this input to the common via the desired load configuration. For example, to connect the LOAD-section input to the common via resistor R1 in series with inductor L2, switches S1 and S8 are set to the I (ON) position, while all the other switches are set to the O (OFF) position.

Figure 1.5: The LOADs.

Thevenin's Theorem:

Thevenin's theorem is named after the French engineer M.L. Thevenin. Thevenin's theorem allows any electrical linear circuit seen at two terminals to be represented by a Thevenin equivalent circuit. The Thevenin equivalent circuit consists of a voltage source, E_{TH}, and an impedance in series with this source, Z_{TH}. Figure 1.6 shows how a simple circuit is thevenized.

- Voltage E_{TH} is equal to the open-circuit voltage, V_{OC}, measured across the two terminals of the circuit to thevenize.
- Impedance Z_{TH} is the impedance seen at the two terminals when the voltage source of the circuit to thevenize is replaced by a short circuit.

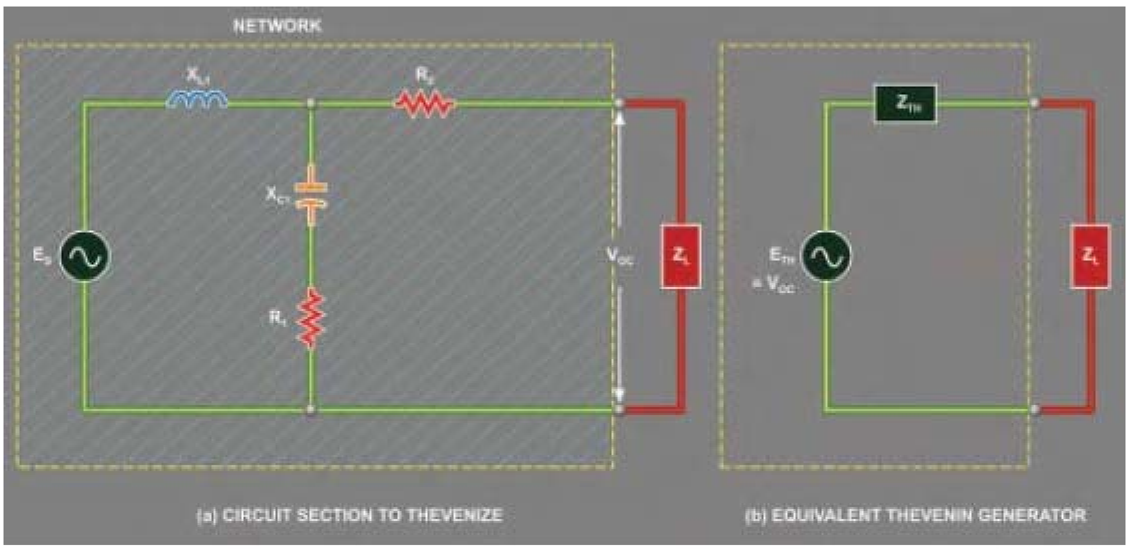

Figure 1.6: Thevenizing a simple circuit

Thevenizing the STEP GENERATOR and the SIGNAL GENERATOR of the TRANSMISSION LINES Circuit Board:

The STEP GENERATOR of the TRANSMISSION LINES circuit board can be represented by its Thevenin equivalent. To determine the Thevenin voltage of the Thevenin equivalent, the STEP GENERATOR output voltage is measured with no load connected to the generator output (that is, with the load impedance in the open circuit condition, equal to ∝ Ω), as Figure 1.7 shows. The measured voltage corresponds to the Thevenin voltage, E_{TH}.

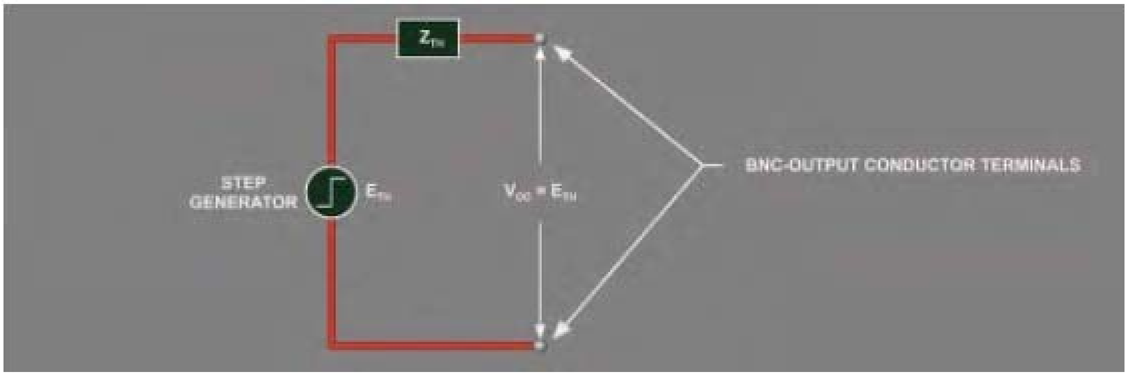

Figure 1.7: Thevenizing the STEP GENERATOR.

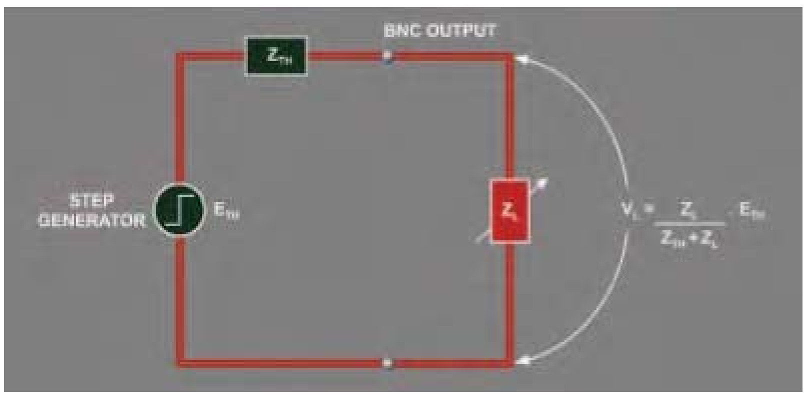

Figure 1.8: Voltage divider rule.

Assuming that the Thevenin impedance of the STEP GENERATOR Thevenin equivalent is purely resistive, this impedance can then be determined by connecting a resistive load, whose resistance can be varied, to the output of the STEP GENERATOR, as Figure 1.8 shows.

According to the voltage divider rule, the voltage across this load, V_L, is

$$V_L = \frac{z_L}{Z_{TH} + Z_L} E_{TH}$$

Where,

V_L=Voltage across the load (V)

Z_L=Load impedance(Ω)

Z_{TH}= Thevenin impedance(Ω)

E_{TH}= Thevenin voltage (V)

When the load is adjusted so that the voltage across it, V_L, is equal to $E_{TH}/2$ (see Figure 1.9), the equation for calculating V_L becomes:

$$\frac{E_{TH}}{2} = \frac{z_L}{Z_{TH} + Z_L} E_{TH}$$

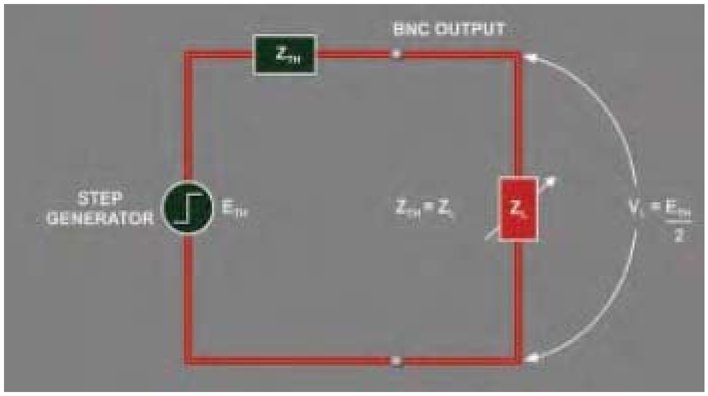

Figure 1.9: $Z_{TH} = Z_L$ when $V_L = E_{TH}/2$.

Rewriting and simplifying this equation for solving Z_{TH}, gives: $Z_{TH}=Z_L$

Consequently, by adjusting the resistance of the load so that $V_L = E_{TH}/2$, and then measuring this resistance, the value of Z_{TH} can be determined. A method identical to that just described can be used to determine the Thevenin equivalent circuit of the SIGNAL GENERATOR of the TRANSMISSION LINES circuit board. As will be seen in detail in the exercise below, a transmission line acts as a load when it is connected to a voltage source. This causes the instantaneous applied voltage to be attenuated by a specific amount determined by the voltage divider rule.